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INTERNATIONAL TSUNAMI INFORMATION CENTER

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TSUNAMI NEWSLETTER is published by the International Tsunami Information Center to bring news and information to scientists, engineers, educators, community protection agencies and governments throughout the world.

We welcome contributions from our readers.

The International Tsunami Information Center is maintained by the U.S. National Oceanic and Atmospheric Administration for the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization. The Center's mission is to mitigate the effects of tsunamis throughout the Pacific.

MEMBER STATES

Present membership of the International Coordination Group for the Tsunami Warning System in the Pacific comprises of the following States:

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PACIFIC TSUNAMI WARNING CENTER

FEATURE

The following article is a reprint from Geophysical Research Letters, Vol. 9, No. 1, pages 25-28, January 1982.

"Tsunami Recorded on the Open Ocean Floor"

By J. H. Filloux

Abstract: On March 14, 1979 a sizeable earthquake (Ms = 7.6, Richter scale) occurred on the continental shelf adjacent to S.W. Mexico, near Petatlan in the state of Guerrero. This earthquake generated a small tsunami that was recorded in deep water, 1000 km away, thus providing for the first time a glance at a tsunami traveling in the open ocean. The same sea floor pressure record displays conspicuous signals associated with vertical sea floor motions generated at the passage of the first Rayleigh seismic wave, R1. Seismic and tsunami travel velocities are in agreement with our present understanding of the phenomena, and tsunami detectability in deep water is demonstrated to be well within present day state of the art in the design of sea floor pressure transducers. As calculations anticipate, the E.M. signals associated with the passage of the tsunami were too faint to be detected.

The recurrent major earthquakes associated with the circumpacific volcanic belt and subduction zones often generate powerful ocean waves, tsunami, which may cause disasters locally as well as on distant shores. Japan has been particularly vulnerable to these treacherous events and tsunami research is strongly supported by Japanese scientists, which may explain retention of "tsunami" to refer to such occurrences (Wilson, 1964). In a strictly ethymological sense, a tsunami is a local ocean wave in a protected and populated embayment (tsu = bay or harbor or both, nami = wave). However, to the Japanese, "tsunami" conveys the extended meaning of a large destructive wave that appears unexpectedly along the coast, unobserved offshore by homebound fishermen unaware of the devastation that sometimes preceded them.

The principal source regions for tsunami are well understood to match the great earthquake zones located at the periphery of the Pacific Ocean - Aleutians, Kamchatka, Kurile, west coast of Central and South America - as well as those adjacent to active volcanic arcs - Japan, Philippines, Sumatra, Solomon, Fiji, Tonga Islands, etc. (Iida, et al., 1967; Kelleher, 1979).

Tsunamigenic earthquakes are believed to be those combining exceptional dip-slip faulting displacements with the most extensive offshore rupture zones (Kajiura, 1970). The mechanism of these earthquakes is itself understood to often involve thrust faulting with a resultant crustal uplift generated by upper plate rebound in a plate to plate interaction area (Plafker, 1979). For this reason, the initial phase of a tsunami is in general positive, initially the sea level rises, although there are exceptions to this often observed case.

In spite of certain established correlations between earthquake characteristics and resultant tsunami properties, the optimum treatment of tsunami generation remains in doubt: divergences in points of view center principally around the concept of oceanic response to the instantaneous displacement of a rigid sea floor (Braddock et al., 1973) and the concept of response to energetic and more complex transitory elastic sea floor distortions (Ward, 1980).

Following generation, tsunami travel across the ocean as exceedingly low profile ($\delta << \lambda$) and very long waves ($\lambda >> h$) at the shallow water wave velocity $(gh)^{1/2}$, (δ wave amplitude, λ wave length, g acceleration of gravity, h oceanic depth), that is at roughly 200 m/s. The considerable reduction of propagation speed, hence of wave length in shoaling water along distant shorelines, results in a considerable magnification of their amplitude (Miller, 1964; Van Dorn, 1968) and often in extensive flooding. Local topography and its attendant refractive distortion of wave fronts compounds the problem by focusing tsunami energy onto preferential coastal features.

The theory of coastal transformation of tsunami impinging on shorelines is probably more manageable than the theory of tsunami generation. Nevertheless, in both instances progress in tsunami research is impeded by the lack of observational guidance. This is, of course, particularly true for the source and near field area where observations would be quite difficult and would require extravagant instrumental arrays, but it also holds for the open ocean where precise observations have become relatively easy to carry out. Yet in his review of a recent international tsunami symposium, Zetler (1981) notes: "A glaring omission in the symposium coverage was the dearth of any mention of open-ocean recordings of tsunami."

Over the last three years we have recorded pressure fluctuations on the sea floor at 12 independent locations of the N.E. Pacific Ocean (Filloux, 1980). In a search for possible evidence of tsunami signals in our records we first noticed that major earthquakes, even quite distant ones, produce conspicuous signatures on deep sea floor records. Specifically, the vertical sea floor motions associated with the earliest seismic energy packet (Rayleigh R1) are sufficiently intense to produce well-defined pressure signals p_s as they accelerate the mass of several kilometers of sea water, with

$$p_s = \rho h \frac{d^2 a}{dt^2} \qquad (1)$$

(p_s = pressure generated by vertical seismic sea floor displacements a; ρ sea water specific mass). We were also pleasantly surprised to discover that one of these recorded seismic events was accompanied by a low amplitude tsunami. This event was too small to have attracted attention in conventional and generally quite noisy tide records, though it is unquestionably resolved in our very low noise sea floor data.

The earthquake referred to above occurred on March 14, 1979 near the Mexican town of Petatlan (Guerrero) approximately halfway between

Acapulco and Manzanillo, see location on the map of Figure 1. Its magnitude, Ms = 7.6 and its epicenter location, a few kilometers offshore, suggested definite tsunamigenic capabilities. However, the moderate focal depth, around 50 km, the low fault plane inclination, 15° or less, and perhaps the very narrow shelf width, 15 km, limited the seismic to oceanic energy transfer. The extent of potential learning to be derived from this event is further limited by the unfortunate absence of additional coastal data. Nevertheless, several interesting features illustrate the feasibility and the value of tsunami observations on the open ocean floor.

The single observation station, P on Figure 1, is located 150 km directly south of the southern-most tip of Baja California, in 3210 m water depth, and at a distance of 981 km from the earthquake epicenter. A segment of the recorded pressure signal covering 5.5 hours is shown on Figure 2. Since the main purpose of recording sea floor pressure variations has been to indirectly infer changes in sea level, such as those of tides, the pressure scale is expressed in terms of sea water head with 1 cm sea water head equivalent to $\rho g\ \Delta h$ $1.02 \times 981 \times 1. = 10^3$ dyne/cm^2 or 100 Pascal. The first 2.5 hours establish the natural background signal level, dominated by the effect of very long surface waves with periods of 2-4 minutes and of 0.1 cm r.m.s. amplitude, but also containing 0.5 to 1. hour fluctuations occasionally reaching 0.2 cm. The record portions shown on Figure 2 has been "detided" first, that is the part of the signal coherent with the gravitational tide forcing potential has been subtracted from the raw data. This treatment was necessary to produce a meaningful illustration since the general slope of the initial data is so steep, due to the overwhelming tide signal, that the tsunami signature becomes inconspicuous, not only because of the abruptness of the slope, but also because of the unavoidable vertical scale reduction.

Shortly after the time of the earthquake (arrow E on Figure 2) large and relatively rapid fluctuations occur which result from vertical accelerations of the oceanic layer during the passage of the seismic perturbation as seen earlier. Their amplitude ranges over 3500 dynes/cm^2 (equivalent water head of 3.5 cm). This "ringing-like" effect is expanded on Figure 3 to include all data points available on the record (sampling rate $2^7 = 128$/h or sampling interval $\Delta t = 28.13$ seconds). It should be noted that the recording scheme involves counting the pulses of a voltage controlled oscillator during the recording interval which is equivalent to averaging the pressure signal over this interval. Thus the direct as well as the aliased contribution of high frequency variations is greatly de-emphasized while the timing of any individual event is uncertain by $\pm\ \Delta t/2 = 14$ seconds.

The first expression of sea floor motion occurs $8 \times 28.13 + Cr \pm 14$ or 262 ± 14 seconds following the onset of the earthquake, resulting in an estimated seismic travel velocity of $3.74 \pm .19$ km/s. (Cr is a precisely established clockrate correction). This velocity estimate appears compatible with that generally accepted for Rayleigh wave propagation over an oceanic path, namely around 4. km/s (Brune, 1969).

In the case of the static approximation, that is when the period of the vertical sea floor motion $T = 2\pi\omega^{-1}$ is long compared with the travel time of sound across the oceanic layer of depth h, the pressure response of sea floor fluctuations of amplitude a at the frequency ω is

$$P_{(\omega)} = a_{(\omega)} \ \omega^2 \rho \ h \ . \tag{2}$$

In the present case, the static approximation is satisfied at all frequencies represented in the record since the Nyquist period is 56 seconds for a travel time through the ocean of 2 seconds (depth 3 km; sound velocity in sea water 1.5 km/s).

Of great importance in equation (2) in the ω^2 term which implies a sensitivity greatly enhanced at higher frequencies, namely a gain of 24 db per octave. To exploit this feature, however, requires the use of adequately fast sampling. In the present record the most energetic part of the pressure signal due to R1 must be missing in the display of Figures 2 and 3 due to time averaging and to the low Nyquist frequency. For the reasons above, the R1 arrival could constitute a reliable indicator of a possible incoming tsunami and could be used to initiate the logging of rapidly sampled pressure data. This technique would alleviate the need for the almost impossible data storage capacity required for continuous recording at a sufficiently fast rate. Even in the absence of tsunami data the recording of R1 and possibly that of R2, R3... would be of definite value to geophysical investigations based on interpretation of seismic data.

It can be seen on Figure 3 that the most active part of the vertical R1 motions lasts roughly 15 minutes and that it takes no less than 40 minutes for a return to the background activity characteristic of pre-earthquake time. This lasting effect may result from aftershocks and also from the possible reverberation of seismic waves over an area tectonically exceedingly complex. In spite of the timely resumption of low noise background, the next Rayleigh arrival, R2, could not be unquestionably identified in the continuation of the record (not shown on Figure 2).

The arrival at Station P of the tsunami perturbation occurs 84 ± 2 minutes following the earthquake, see Figure 2. Although of relatively small amplitude, the pressure signal generated by changes in sea level emerges readily from the background. The initial phase is a rise of sea level as often observed. The first three cycles are the most conspicuous ones, with an amplitude near .45 cm and a period around 44 minutes. The following fluctuations distinguishable against the background noise are of reduced amplitude and sharply increased frequency. This effect would require additional data to be clarified. It probably involves some degree of noise interference as well as contributions from distorted reflections and refractions associated with complicated bathymetry in the vicinity of large irregular coastal features such as Baja peninsula and Gulf of California: the frequency shift seems too large and too sudden to result from dispersion properties alone.

It is generally believed that the period characteristic of a tsunami is commensurable with the travel time of the initial perturbation across the source zone. The 44 minute period of the first cycle is surprisingly long for a shelf width as narrow as 15 km. This suggests that most of the energy conversion must have occurred in shoal waters in close vicinity to the coastline: the estimated location of the earthquake epicenter is indeed nearly coincident with the coast.

The distance of 981 km separating source and observation point leads to an average travel velocity of 194 ± 5 m/s. This velocity is consistent with the average depth over the area lying directly between the earthquake epicenter and the recording station, namely 3600 ± 100 m, and with the tsunami traveling at $(gh)^{1/2} = 188 \pm 3$ m/s.

Meaningful interpretations of tsunami observations should be capable of relating these observations to the significant parameters of the source earthquake through the transfer properties of the swept area. In turn, this analysis should cast light on generation and transmission processes. This task is not considered here and it would probably be tightly restricted by the limited extent of observations. Nevertheless, a preliminary estimate of the field of the Petatlan tsunami elevations by Ward following the approach of a recent paper (Ward, 1981) suggests that the pressure instrument was located in an area of minimal tsunami elevation, with an estimated .8 cm upper limit, against .45 observed. In view of many unknowns, the agreement is acceptable and the divergence is consonant with the reduced earth to ocean coupling implied earlier when attempting to explain the relatively long tsunami period.

The tsunami event discussed above was recorded during a sea floor magnetotelluric(MT) experiment (Filloux, 1981) involving sea bottom recording of natural electric and magnetic pulsations, see Figure 1. Although the interaction of oceanic water motion with the main magnetic earthfield do produce electric fields and also magnetic fields as a result of the electric current thus generated these fields were verified to be much too small to have been recorded.

<u>Conclusion</u>: Recording of tsunamis in deep water can be beneficial for 2 principal reasons, namely: (1) to enhance the precise predictability of destructive tsunamis at least hours before coastal exposure; and (2) to provide observational data extremely valuable, firstly in reconstituting the generally little known sequence of seismic motions that generate tsunamis, and secondly in upgrading theories of shoaling transformation.

In spite of its minimal energy, but perhaps also because of its very modest amplitude, the deep water tsunami event discussed here indicates that the early detectability potential of any threatening tsunami is unquestionable. It is also of great interest that the sea floor pressure transducers which permit tsunami detection are also very sensitive to the seismic impulses that occur during the tsunami generation phase. This additional information could play a valuable role in the implementation of a tsunami warning system.

Acknowledgement: This work has been supported by the National Science Foundation, Grants OCE78-14524, OCE78-25324 and OCE79-18382. This paper was written under the encouragement of B. Zetler. Comments, criticisms and suggestions were provided by W. Van Dorn. Discussions with T. Masters, J. Orcutt and M. Reichle helped us interpret the seismic information. Tsunami generation was discussed with S. Ward who contributed a check of observed against predicted amplitudes.

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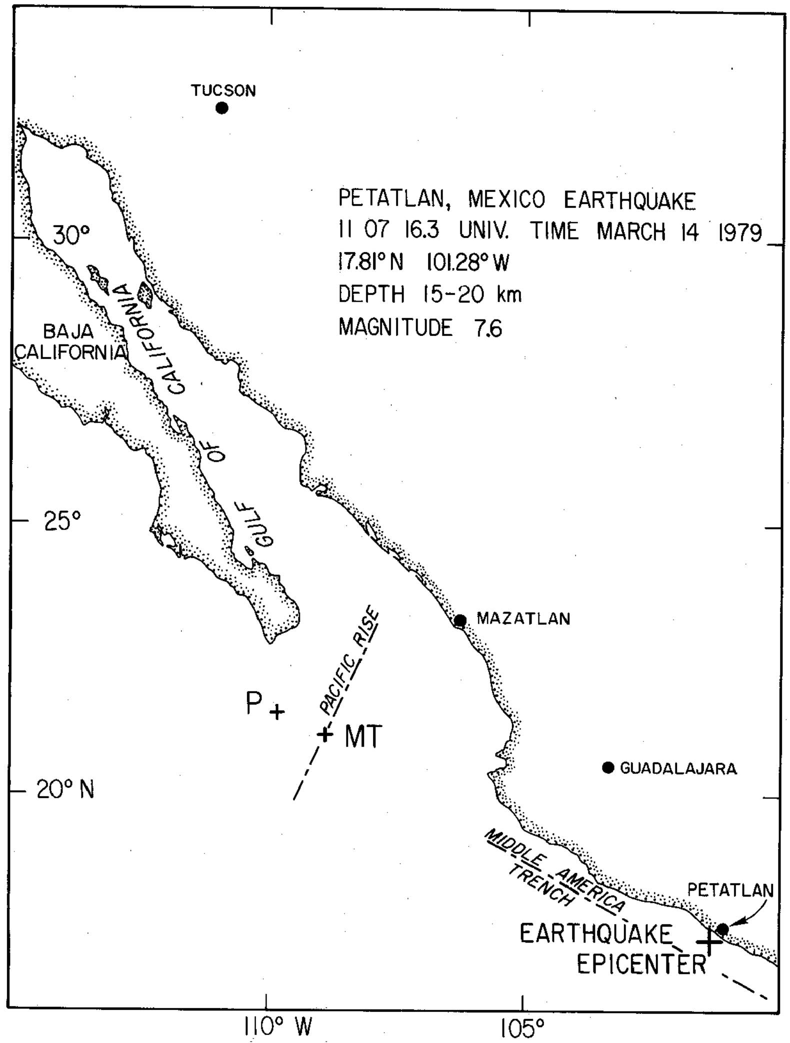

Fig. 1. Location of earthquake epicenter, lower right and of the sea floor experimental area: P, pressure observations; MT, magnetotelluric observations at 4 sites along P-MT. Note the complexity of oceanic boundaries.

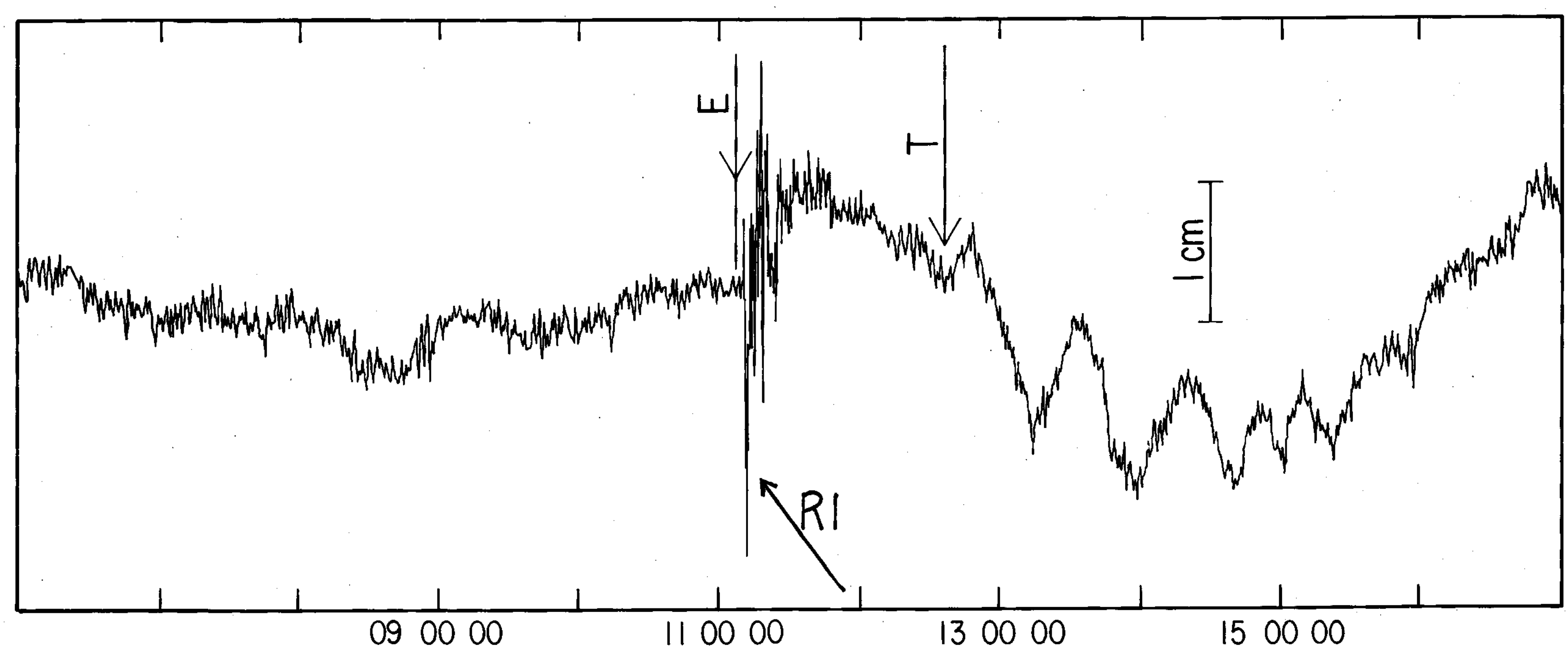

Fig. 2. Sea floor record centered around the time of the Petatlan earthquake. The time of occurrence of the earthquake is marked by arrow E. It is followed a few minutes later by the arrival of the seismic perturbation R1. A small tsunami follows roughly 1.5 hours later time marked by arrow T. The pervasive small high frequency ripples with period 2-4 minutes and amplitude around 0.1 cm are the pressure signature of very long surface waves. The pressure scale is referred to the pressure created by a one cm change of sea level, which is equivalent to a pressure of approximately 1000 dynes/cm^2 or 100 pascals.

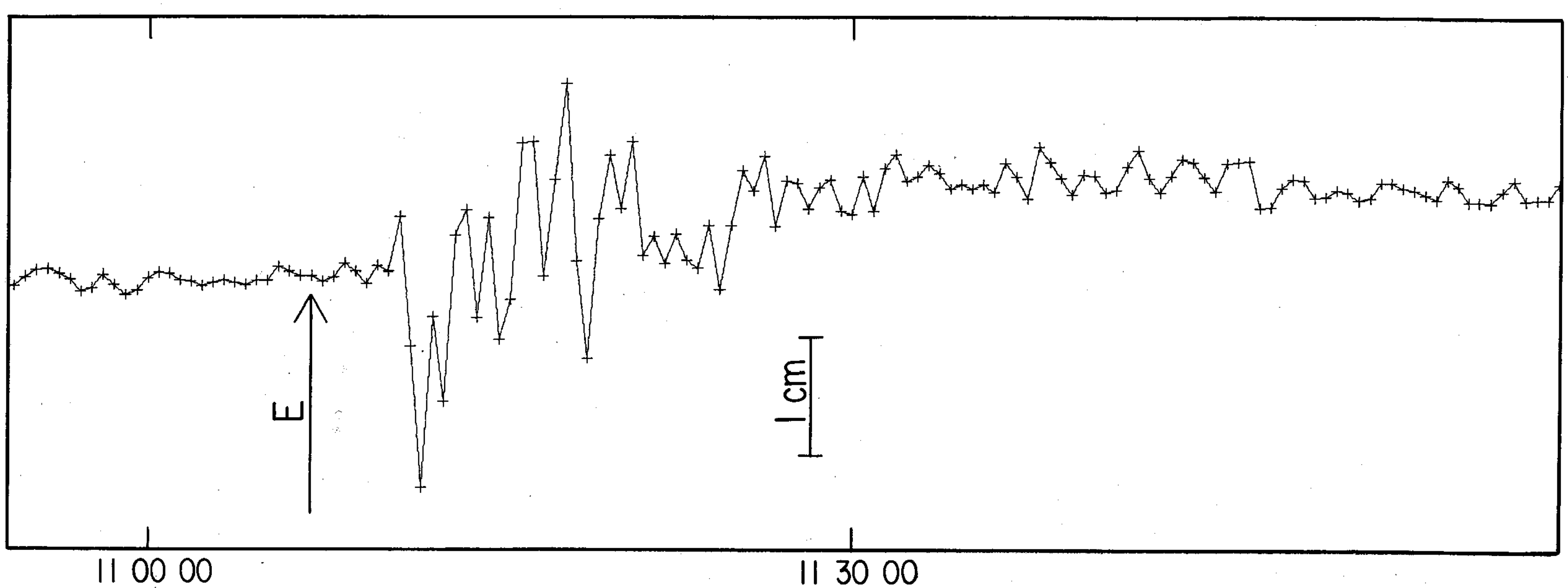

Fig. 3. The pressure signal associated with the Rayleigh R1 seismic perturbation is expanded to show the individual points of the recorded data (sample rate 128/hour or Δt = 28.13 seconds). The pressure scale is defined as in Fig. 2. Note the long time delay required after the earthquake and before the arrival of the tsunami for the pre-earthquake background noise level to be resumed. (The time scale is with respect to the instrument clock which is itself 42 seconds behind Universal Time).

NEWS EVENTS

Tidal Wave in Java, Indonesia, February 24, 1982

According to the May issue of UNDRO News, there were minor tidal waves reported when a series of earthquakes occurred near the City of Medan, Indonesia. The Preliminary Determination of Epicenters reported an earthquake of a magnitude of 5.4. The earthquake occurred on February 24, at 0422 (GMT) and centered at 4.4°N and 97.7°E in the northern Sumatra area. A magnitude of 5.4 is usually not strong enough to generate any wave. The International Tsunami Information Center is in the process of contacting the Indonesian authorities on more details of this event and will report in the next issue of the Tsunami Newsletter.

Earthquake in Hokkaido, Japan, March 21, 1982

On March 21, at 0232 (GMT), an earthquake measuring at 6.9 on the Richter scale struck Japan. The quake centered at 42.15°N and 142.55°E, about 100 km southeast of Sapporo just off the coast, injured more than 110 persons and caused considerable property damage and landslides in south Hokkaido. A 24-cm tsunami was recorded at Hachinohe, and a 21-cm tsunami was recorded at Urakawa at 0240 (GMT) which rose to 80 cm at 0320 (GMT). Urakawa is located about 25 km east of the epicenter and the hardest hit area.

Earthquake in El Salvador, June 19, 1982

An earthquake, measuring 6.9 on the Richter scale, hit El Salvador and Guatemala on June 19 at 0622 (GMT). The quake centered at 13.3°N and 88.4°W, 50 miles from San Salvador, the capital of El Salvador. Serious damages were reported along the border with Guatemala where virtually all roads linking the two countries were blocked by landslides.

At least a total of 16 people were reported killed in the two countries. The villages of San Miguel Tepezontes and San Juan Tepezontes, both 21 miles southeast of San Salvador, were said to have been all but destroyed. At least 2 people were killed and 73 injured in San Miguel. 750 people were left homeless in Jalpatagua in Guatemala. The quake was also felt in Nicaragua and Hondura, but there were no immediate reports of injuries or damage.

INTERNATIONAL TSUNAMI INFORMATION CENTER

Associate Director, ITIC

The secondment of Gerry Dohler as Associate Director to the International Tsunami Information Center (ITIC) was announced at the Fifteenth Session of the Intergovernmental Oceanographic Commission (IOC) Executive Council, March 1982, and the Eighth Session of the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), April 1982.

Gerry has taken up his new duties as of July 1, 1982. The initial secondment supported by the Government of Canada will be for a period of one year.

Gerry Dohler is a Professional Engineer and since 1941 has been continuously involved in many aspects of Oceanography and Hydrography in Europe, the Far East and North America. For the last seven years he was Director of Marine Cartography, and implemented for the Canadian Hydrographic Service the computer assisted cartographic techniques in the chart production process. He has written many papers in the field of tides, currents and water levels, and was responsible prior to his last appointment to build a modern tidal establishment in Canada. He is a member of ITSU since its first session, and for the last several years Chairman of the Group.

During the period of the secondment, George Pararas-Carayannis, Director, and Gerry Dohler will work in close cooperation to fulfill the mandate of ITIC, and to ensure that the resolutions and recommendations prepared at ITSU meetings are applied for the benefit of those living in the tsunami prone areas of the Pacific.

Director, ITIC Participates in ITSU VIII Meeting in Suva, Fiji

Dr. George Pararas-Carayannis, Director of ITIC, participated in the Eighth Session of the International Coordination Group for the Tsunami Warning System in the Pacific, in Suva, Fiji on 13-17 April 1982. Dr. Pararas-Carayannis presented his biannual (1980-1982) report of progress by the International Tsunami Information Center. Copies of the biannual report were circulated to all national contacts of ITSU Member States a month before the Conference.

Former Associate Directors Visit ITIC

Mr. Norman Ridgway (Associate Director, ITIC, 1978-1979), received financial support from UNESCO-IOC to visit ITIC at the end of July. During his visit, Mr. Ridgway will work on the editing and compilation of a Catalog of Tide Gauge Stations in the Pacific Ocean. In addition, he will complete the work on a slide-tape presentation on tsunami, an educational project that was started while at ITIC.

Mr. Sydney Wigen (Associate Director, ITIC, 1976-1978), currently the ITSU National Contact for Canada, will also visit ITIC in the beginning of August. He will work with the Director and Associate Director on the ITSU VIII Meeting resolutions.

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List of National Contacts of ICG/ITSU

The following is a list of National Contacts of ITSU members on file in the ITIC office. Please inform ITIC if there are any changes.

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ITSU VIII Meeting Held in Fiji

The Intergovernmental Oceanographic Commission's International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU) held its Eighth Session in Suva, Fiji on 13-17 April 1982. The agenda of the meeting was published in a previous report. The summary report of the session will be published in the following issue of the Newsletter together with the resolutions.

Participants of the Eight Session of the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), in Suva, Fiji on 13-17 April 1982.

Front Row, L-R : Capt. D. Naidu, Dr D. Tiffin, Dr. N. Yamakawa, Mr. R. Valera, Mr. G. Prasad, Miss M. Smith, Dr. G. Flittner

Second Row, L-R: Mr. G. Linga, Mr. Lautiki, Mr. H. Plummer, Dr. G. Dohler, Dr. I. Oliounine, Mr. Lee Joe, Mr. I. Everingham

Third Row, L-R : Mr. J. Buakula, Col. A. Quiaoit, Mr. J. J. Tulele, Mr. W. Garcia, Mr. V. Faucheux, Dr. G. Burton

Top Row, L-R : Mr. P. Rakoroi, Mr. M. Spaeth, Mr. J. Flavell, Dr. G. Pararas-Carayannis, Mr. N. Ridgway, Mr. S. Tonganilava, Mr. H. deGraaf

NATIONAL AND AREA REPORTS

Tsunami Stations Inspection

The Pacific Tide Party personnel completed the annual inspection for the following stations:

Crescent City, California	Nov. 18, 1981
Honolulu, Hawaii	Jan. 6, 1982
Wake Island	Jan. 12
Nawiliwili, Hawaii	Jan. 18-20
Kahului, Hawaii	Jan. 22-26
Hilo, Hawaii	Jan. 27
Pago Pago, American Samoa	Feb. 2-6
Johnston Atoll	Feb. 3-6
Midway Island	Feb. 9
Kwajalein	Feb. 6-10
Truk Atoll	Feb. 11-14
Guam	Feb. 14-16, 21-23
Malakal, Palau	Feb. 18
Fort Point, California	Mar. 27

The Government of Marshall Islands Renamed

The Marshall Islands has been renamed "Republic of the Marshall Islands." The head of the Republic is President Amata Kabua.

ANNOUNCEMENTS

United States Earthquakes, 1979 Available

This new volume is now available from:

The National Geophysical & Solar-Terrestrial Data Center
National Oceanic & Atmospheric Administration (NOAA)
325 Broadway
Boulder, Colorado 80303
U.S.A.

The publication provides a summary of all earthquakes that occurred in the United States and nearby territories during 1979. It also contains: a summary of felt and damaged data reported for each earthquake, a list of earthquakes by state, results from local seismic networks, information on crustal movements, tsunamis, principal earthquakes of the world, and strong-motion seismograph data. There are 67 earthquake maps and graphs, 9 tables, 34 references, and 4 photographs.

Proceedings of the International Tsunami Symposium 1981

The above proceedings titled as "The Tsunamis, their Science and Engineering: The Proceedings of the International Tsunami Symposium 1981," edited by K. Iida and T. Iwasaki will soon be available. All business correspondences concerning the publication should be sent to:

Terra Scientific Publishing Company
Shibuya-dai Heim 307
4-17, Sakuragaoka-cho
Shibuya-ku
Tokyo 150, Japan

The oversea distribution of the publication will be handled by:

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Eighth World Conference on Earthquake Engineering

The above mentioned Conference will be held from July 21 to 28, 1984 in San Francisco, California, U.S.A. The purpose of the Conference is to foster the advancement of earthquake engineering by providing a forum where participants from all related disciplines can meet to exchange ideas and information on recent developments.

The technical session of the Conference will cover all aspects of earthquake engineering including seismic risk and hazard; ground motion and seismicity; experimental methods and tests of structures and components; development and enforcement of seismic codes and standards ... etc.

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ABSTRACTS

Assessment of Tsunami Hazard Presented by Possible Seismic Events: Far-Field Effects

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The purpose of this study is to model the propagation of tsunamis from source regions off the west coast of South America to the continental shelf zone of Alaska, Japan, the Philippines, Australia, and New Zealand. The simulations were carried out by numerically solving the linear, inviscid equations for long waves. Potential generating areas were chosen by identifying seismic gaps in the Peru-Chile Trench area. Ocean bottom displacements in each source area were specified on the basis of representative earthquake parameters (depth, dip angle, fault length and width, slip displacement) chosen from an examination of historical seismicity patterns in the area.

Areas of maximum offshore wave height were identified along each coastline in response to each earthquake/tsunami event. Several coastal areas were subjected to high concentrations of wave energy no matter where the source was located. These areas warrant more detailed study. Recommendations are made concerning the use of the present study in tsunami hazard education and planning efforts, as well as for further work based on these results.

Assessment of Tsunami Hazard Presented by Possible Seismic Events: Near-Source Effects

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The purpose of this study is to model the propagation of tsunamis along the continental shelf up and down coast of earthquake source regions near the Peru-Chile Trench. The simulations were carried out by numerically solving the linear, inviscid equations for long waves. Potential generating areas were chosen by identifying seismic gaps in the Peru-Chile Trench area. Ocean bottom displacements in each source area were specified on the basis of representative earthquake parameters (depth, dip angle, fault length and width, slip displacement) chosen from an examination of historical seismicity patterns in the area.

Areas of maximum offshore wave height were identified along the coastline in response to each earthquake/tsunami event. Several coastal areas were subjected to high concentrations of wave energy no matter where the source

was located. These areas warrant more detailed study. Recommendations are made concerning the use of the present study in tsunami hazard education and planning efforts, as well as for further work based on these results.

Pressure Fluctuation on the Open Ocean Floor Over a Broad Frequency Range: New Program and Early Results

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[Journal of Physical Oceanography, Vol. 10, No. 12, December 1980, American Meteorological Society]

A two-month ocean-floor pressure record obtained 330 km to the east of the main island of Hawaii by means of a Bourdon tube-type transducer with optical readout is discussed in detail. An approach to subtraction of the drift component associated with plastic flow of the heavily strained transducer is assessed. In spite of a 40 m progressively accumulated error, it is shown that fluctuations with periods as long as a few cycles per record length are resolved with a remarkable precision. The lunar fortnightly tide, with its period around 14 days, for instance, appears to be in error by no more than 0.3 cm, on the assumption that the transfer function between gravitational driving corrected for earth tides and sea floor pressure has a modulus of 0.7 and a negligible phase shift.

Eleven tidal constituents in each of the diurnal and semidiurnal bands, as well as constituents M3 and Mf are tabulated. These estimated tidal constants come within a few percent of those published for Hilo, revealing a relative uniformity of tidal behavior for this area. The use of tide constants from Hilo to check or to constrain mathematical models of the Pacific tides thus appears acceptable.

Because of its inherent high-frequency response and its high accuracy (response up to 1 cycle per second; resolution 0.0206 cm in present data) the instrumentation used in the experiment described here can contribute to the investigation of a variety of problems of ocean geophysics. For instance, the low-frequency end of the surface wind-generated wave spectrum is clearly resolved and is shown to vary slowly from day to day with considerable variations over weekly or longer time spans.

The close approach on 20 July 1978 of Tropical Cyclone Fico to the area of our sea-floor station provided an opportunity to investigate its effect on sea-floor pressure fluctuations. Although somewhat disappointing, this attempt does stress the great advantage to be gained by using an array of stations rather than individual ones to identify and to sort out the many processes at play.

Tsunami Energy in Relation to Parameters of the Earthquake Fault Model

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[Bulletin of the Earthquake Research Institute, Vol. 56 (1981), pp. 415-440]

Tsunami genergy generated by an earthquake is estimated on the basis of a simple fault origin model of the earthquake. Tsunami energy E_t is given by

$$\log E_t(\text{ergs}) = 2M_w + \log F + 5.5$$

where M_w is the moment-magnitude of earthquake and F is a function of fault parameters (maximum F is about 0.1), such as the dip angle δ, slip angle λ and the relative depth $h^*(=H^*/L$; where H^* is the mean depth of the fault plane with the length L and width W). The aspect ratio (=W/L) is assumed to be 1/2.

The variation of F with respect to the full range of δ, λ, or $h^*(<1.0)$ is about a factor of 10. In particular, the difference of tsunami energy between the vertical faults with the dip and strike slips is conspicuous. Since the depth dependence of the tsunami energy is given in terms of the relative depth h^*, the decrease of energy with the increase of the fault depth H^* is more significant for smaller earthquakes.

The results are compared with empirical values of tsunami energy published so far. The general trend of $\log E_t$ with respect to M_w is consistent with the above formula. However, it is noted that the values of tsunami energy derived in the past on the basis of the energy flux method were systematically overestimated by a factor of 10 or more. On the other hand, the maximum tsunami energy (Chilean earthquake of 1960) would be around 10^{23} ergs and somewhat lower than the value expected from the formula.

Numerical Experiments for the Tsunamis Generated off the Coast of the Nankaido District

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Source models of past tsunamis generated off the Pacific coast in the Nankaido district are examined by the trial and error method of numerical experiments on the basis of seismic fault models.

The fault model for the 1946 Nankai earthquake consists of the eastern and the western fault planes. The peculiarity of this model is that the western margin of the fault is located 30 km eastward of Ashizuri-Misaki and the dip angle of the eastern fault plane is as low as 10 degrees. It may be difficult to define uniquely the duration time of the bottom deformation from the results of present numerical experiments. The prevailing speculation, though, seems to be that the duration time of the western part is 3 to 10 minutes, which is slower than that of the eastern part.

The reliability factor, κ, of the model, a logarithmic standard deviation of the ratios of observed and computed values for five reference stations, is 1.12.

The fault model for the 1854 Ansei-Nankai tsunami is 30 km longer in the western fault and 15% larger in the slip displacement than that for the 1946 tsunami. The computed tsunami height at Osaka is 2.4 meters, which is smaller than the published estimated value, $2.5\sim3$ meters. However, since Osaka is situated on the delta of the Yodo river and has many small canals, a tsunami 2.4 meters high at shore may invade canals as waves like bores and do tremendous damages to many boats and bridges, just as described in old documents.

In the 1707 Hoei-Nankai tsunami, the tsunami heights at the southwestern region of Shikoku were about 1.5 times higher and the uplift at Muroto-saki about 2 times larger than those of the 1854 tsunami. Therefore, the fault model similar to the 1854 earthquake cannot explain the above characteristics. A model having three separate faults is proposed for this tsunami.

[In Japanese]

The New Tsunami Recorders (ERI-V) at the Enoshima and the Izu-Oshima Tsunami Observatories

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New instruments for measuring long-period ocean waves were installed at the Enoshima Tsunami Observatory in March 1980 and at the Izu-Oshima Tsunami Observatory in March 1981. A quartz-crystal resonator applying the principle of piezoelectric excitation is used as the water pressure transducer for measurements of sea-surface variation. Values of sea surface elevation calculated from the transducer's output are successively stored at 30 second intervals to one of a pair of IC memories which are alternately used every other day. The data on the memory, which consists of 2880 samples every day and can be automatically or manually copied on a floppy disk to preserve them the next day, is expressed by integers of six figures in 0.1 millimeters.

Tide data (0-5 m) obtained by low-pass filtering of 3 min and long-period wave data (±50 cm) obtained by high-pass filtering of 180 min are converted to analog signals and recorded by a two-pen recorder as a monitor. Hourly and daily mean sea levels and power spectrum for the 24 hours data of long-period waves are computed and printed out by a digital printer.

These instruments are operating quite well at both tsunami observatories. A small tsunami (about 10 cm) accompanying the earthquake on Jan. 19, 1981 was observed at Enoshima. Spectra of long-period variations of the sea surface are obtained every day and have been analyzed as a clue to finding the general feature of shallow water oscillations. It is expected that the data accumulated by this instrument will elucidate the origin of generation and the mechanism of long-period sea surface variations.

[In Japanese]

Tsunami Sources in the Sanriku Region in 1979 and 1981, Northeastern Japan -- Seismic Gap off Miyagi

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[Bulletin of the Earthquake Research Institute, Vol. 56 (1981), pp.629-640]

Two small tsunamis generated far off Iwate on Feb. 20, 1979 and off Miyagi on Jan. 19, 1981 are investigated, by using the tide-gauge records. From the amplitude-distance diagram, the magnitude (Imamura-Iida scale: m) of the 1979 and 1981 tsunamis are determined to be $m = -0.5$ and 0, respectively. The source area of the 1979 Iwateoki tsunami was located near the Japan Trench and the length was 50 km. The source area of the 1981 tsunami lay on the east side of the 1978 Miyagi-oki tsunami ($m = 0.5$) and the length was 60 km in an east-west direction. These source dimensions are nearly standard for earthquakes of magnitude (M 6.5-7.0).

In the space distribution of tsunami sources during the past 85 years (1897-1981), a remarkable seismic gap can be seen in a segment of 150-200 km along the trench far off Miyagi. In the southern Sanriku region, no event has occurred for at least 85 years since the earthquake of Aug. 5, 1897 ($M = 7.7$). This 1897 tsunami ($m = 2$) caused much damage to houses with waves 2-3 meters high. A segment of 200 km far off Miyagi should be considered as an area of relatively high tsunami risk.

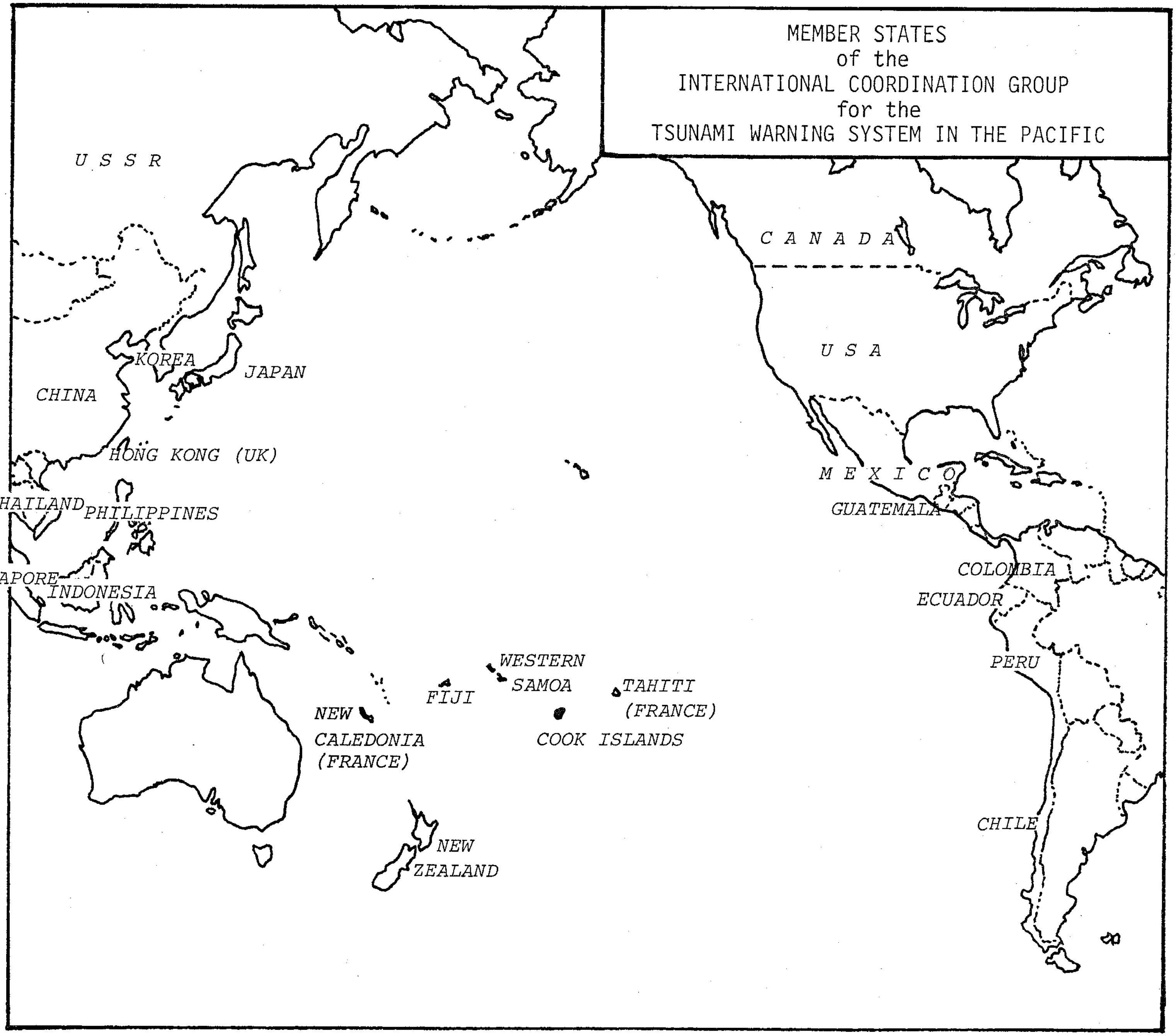
PACIFIC TSUNAMI WARNING CENTER

Minister of Civil Defense, New Zealand Visited Hawaii

The Honorable Allan Higher, Minister of Civil Defense of New Zealand toured Pacific Tsunami Warning Center during his recent visit to Honolulu (July 22-24, 1982).

Seismic Summary (March 1, 1982 to Press Time)

EVENT NO.		EVENT	LOCATION	ACTION TAKEN
1982-5	(PTWC)	Mar 21 0232 (UT) 6.8	Vicinity of Honshu, Japan 42.3 N 142.0 E	Press Release
1982-6	(PTWC)	Jun 7 0652 (UT) 6.9	Oaxaca Province, Mexico 16.3 N 97.2 W	Press Release
1982-7	(PTWC)	Jun 7 1059 (UT) 6.9	Oaxaca Province, Mexico 16.4 N 97.6 W	Press Release
1982-8	(PTWC)	Jun 19 0622 (UT) 6.9	San Salvador, El Salvador 13.3 N 88.4 W	Press Release
1982-9	(PTWC)	Jun 30 0157 (UT) 6.7	Kurile Islands 44.7 N 150.6 E	Press Release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